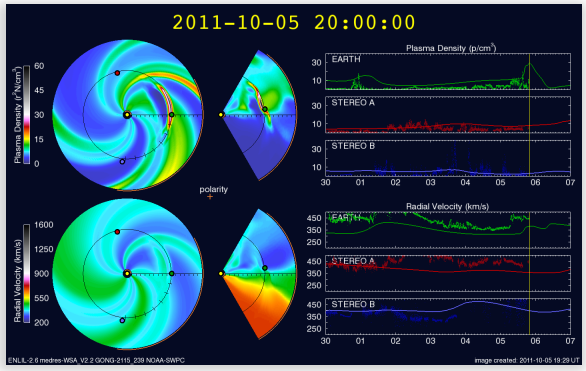
Transitioning Research Models to Operations

2 examples of problems and challenges

George Millward
CU CIRES / NOAA SWPC

Model transitions from SWPC -> NCEP

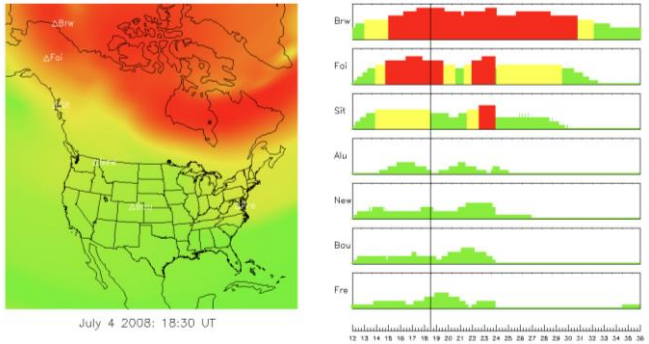
WSA-Enlil Heliospheric model transition: 2009 – 2012



Problems encountered building Inputs in an operational context.

SWMF Magnetospheric Geospace model: 2014 – 2015

regional geo-magnetic activity prediction



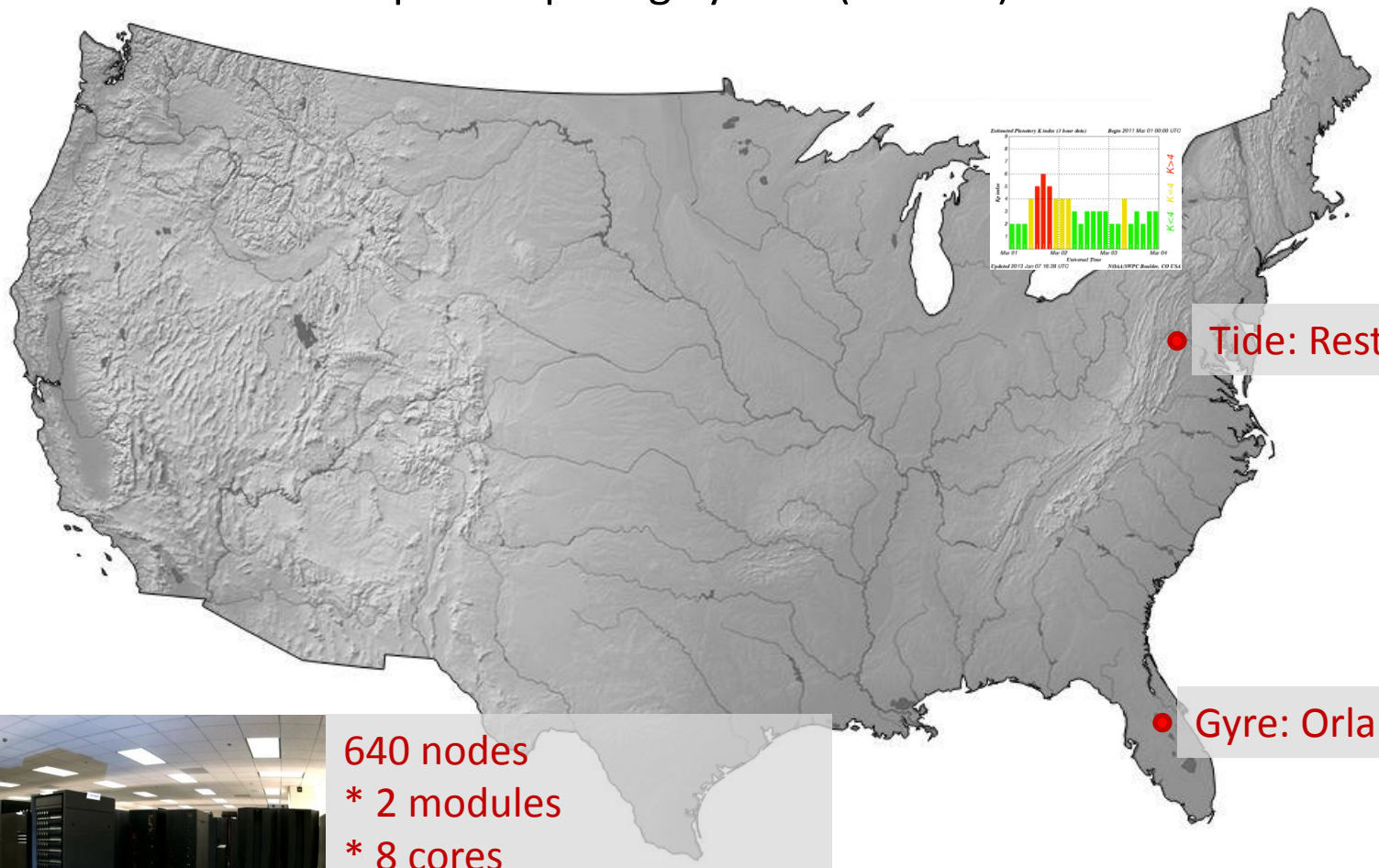
Investigating real-time operations for Geospace

NCEP Weather and Climate Operational Supercomputing System (WCOSS)

640 nodes
* 2 modules
* 8 cores
* 2 hardware threads
= 20480 things

- Tide: Reston, VA
- Gyre: Orlando, FL

NCEP Weather and Climate Operational Supercomputing System (WCOSS)



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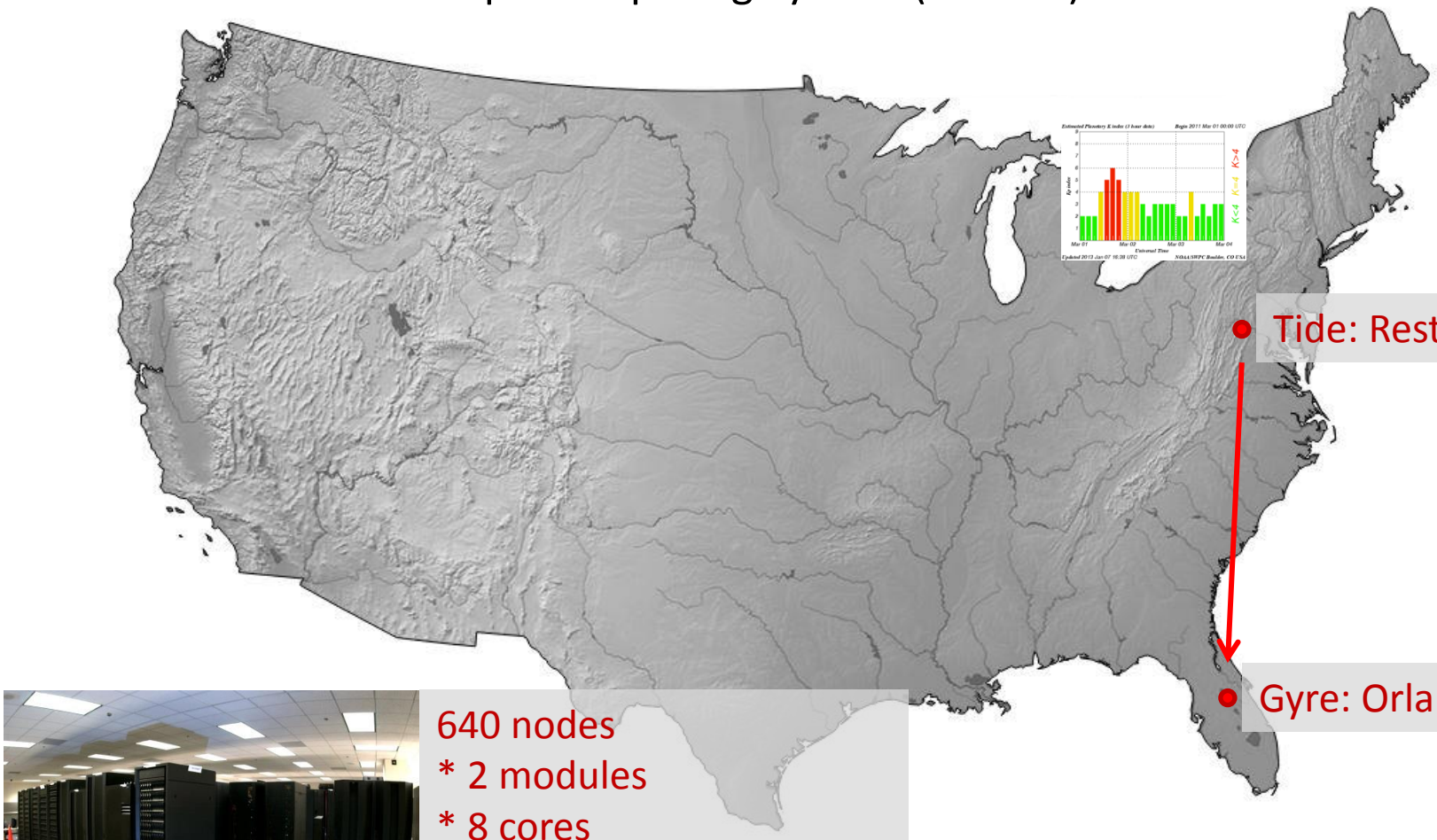

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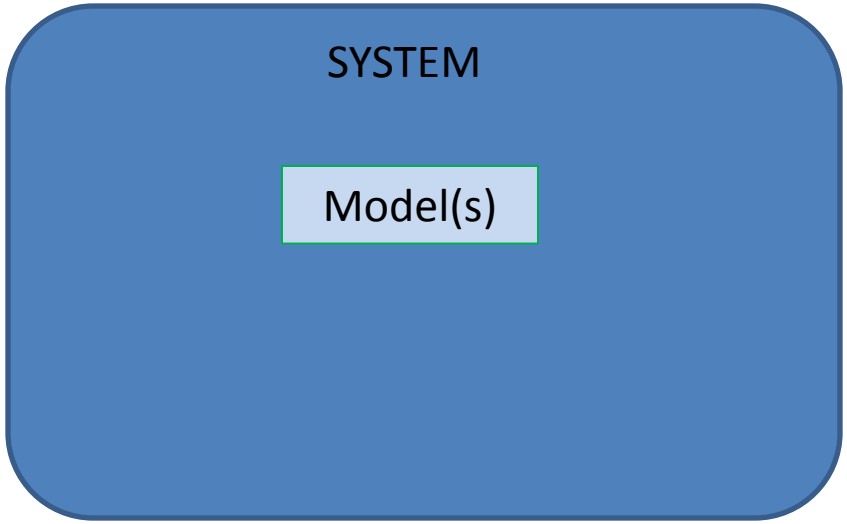
Computer modeling in research context:

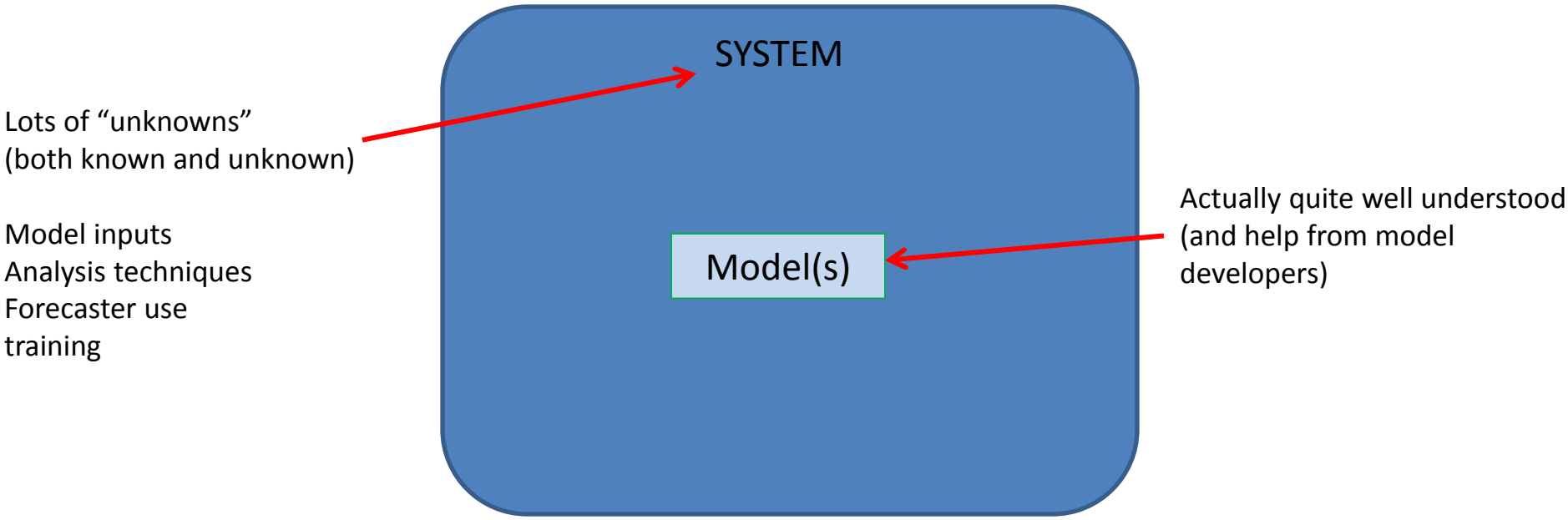
Aim is to demonstrate/understand fundamental scientific principles (and/or complex physical systems) via Physics, Mathematics and suitable approximations.

……in the process the modeling may provide a correct answer (or a partially correct answer)

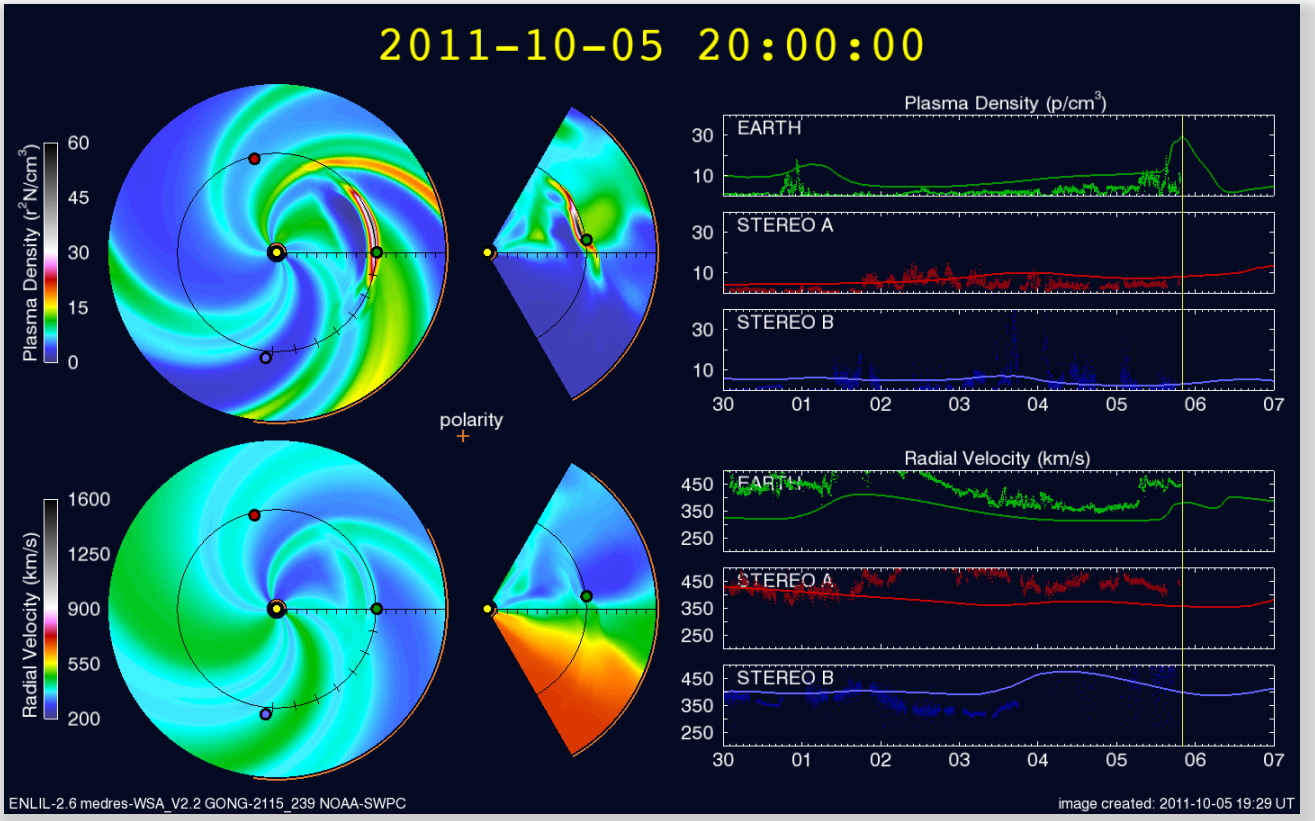
Computer modeling in an operational context:

The model's ability to produce a correct answer can be exploited and form the core of an operational SYSTEM to forecast some (useful) information ahead of time.

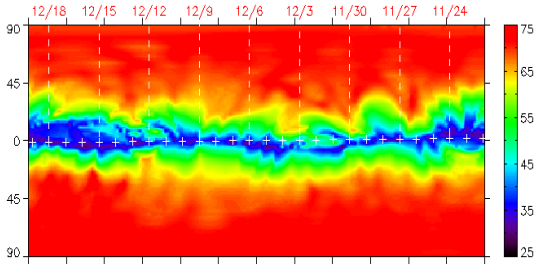


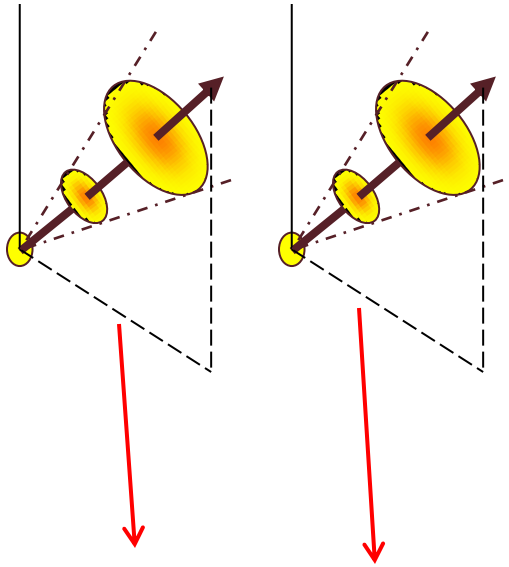

SYSTEM
Lots of “unknowns”
(both known and unknown)
Model inputs
Analysis techniques
Forecaster use
training
Model(s)
Actually quite well understood
(and help from model
developers)

Example: WSA-Enlil (transitioned to NCEP - 2009 to 2011)



WSA-Enlil Model Run Schematic





CME 1

CME 2

10 day model startup

5 days CME injection

forecast

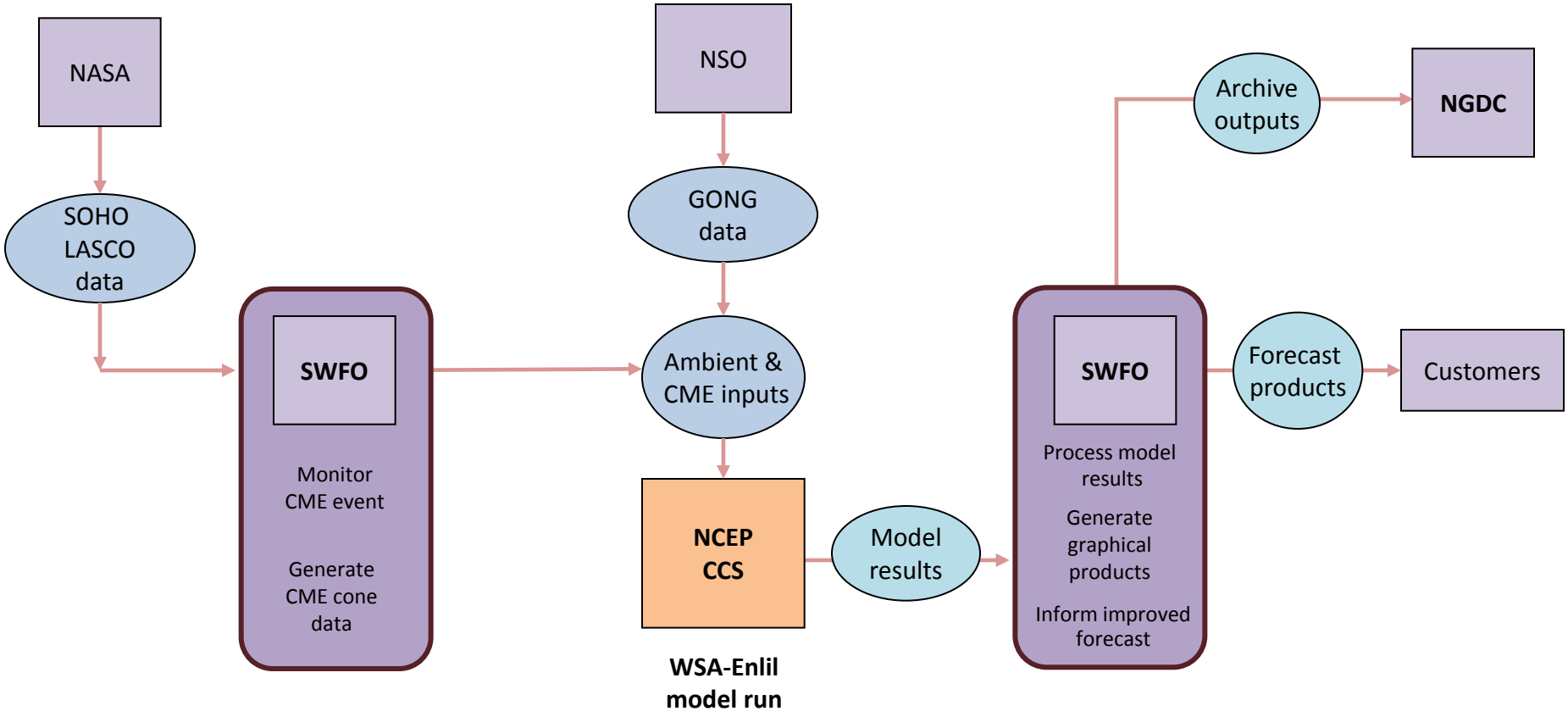
T = -15

T = 0

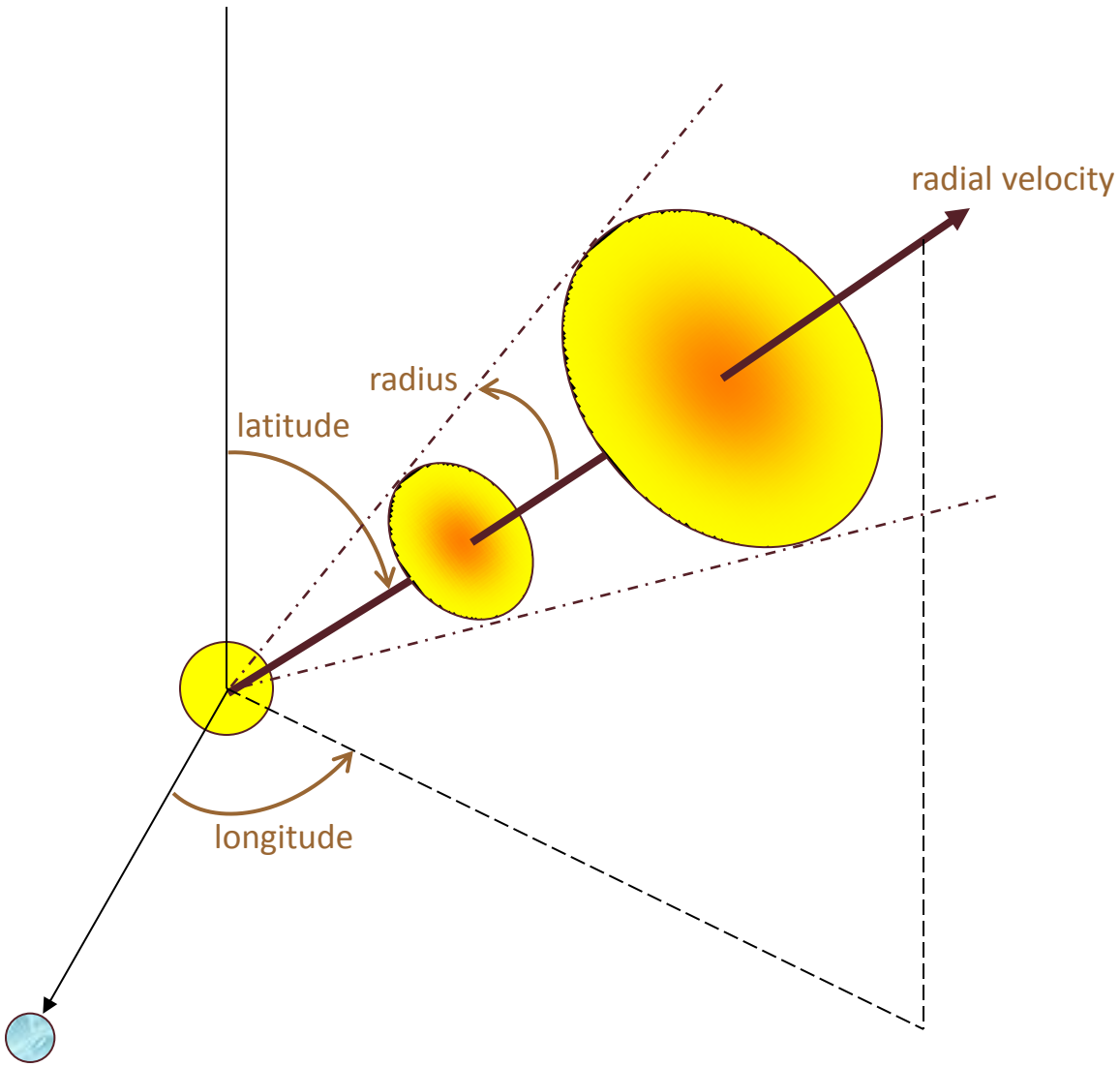
T = 5 days

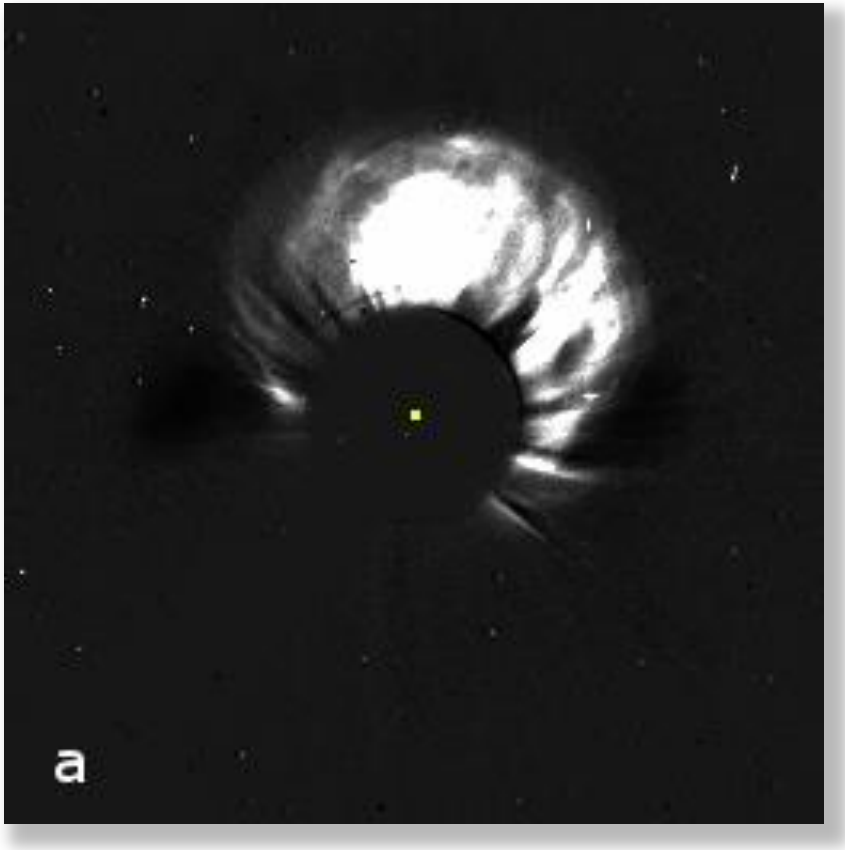
1.5 hours Wallclock time on NWS CCS

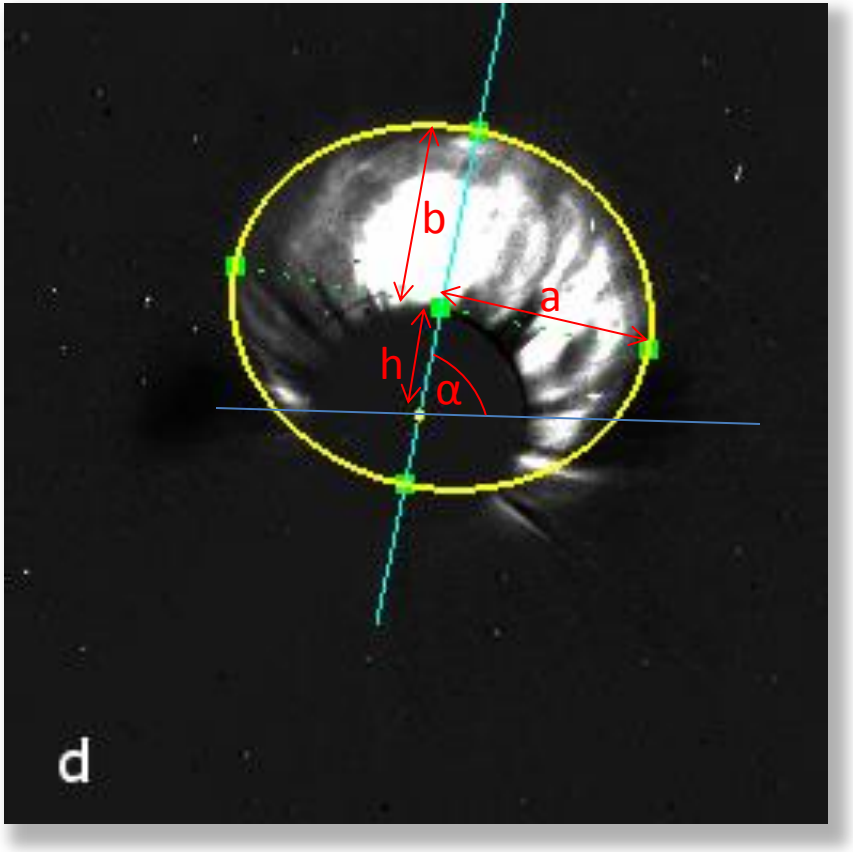
WSA-Enlil CONOPS



CME ‘Cone’ Geometry

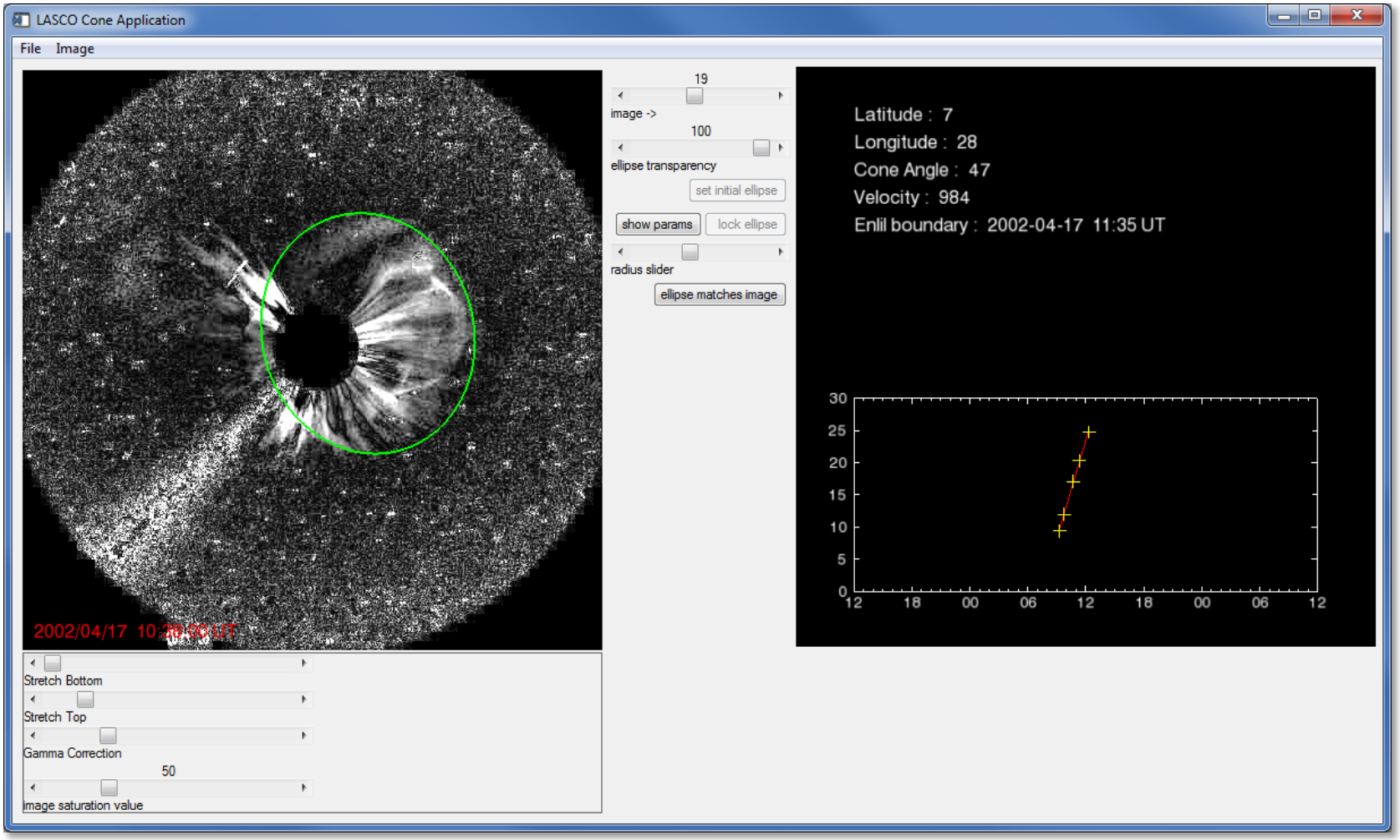



a



Ellipse parameters gives CME propagation direction and cone angle.

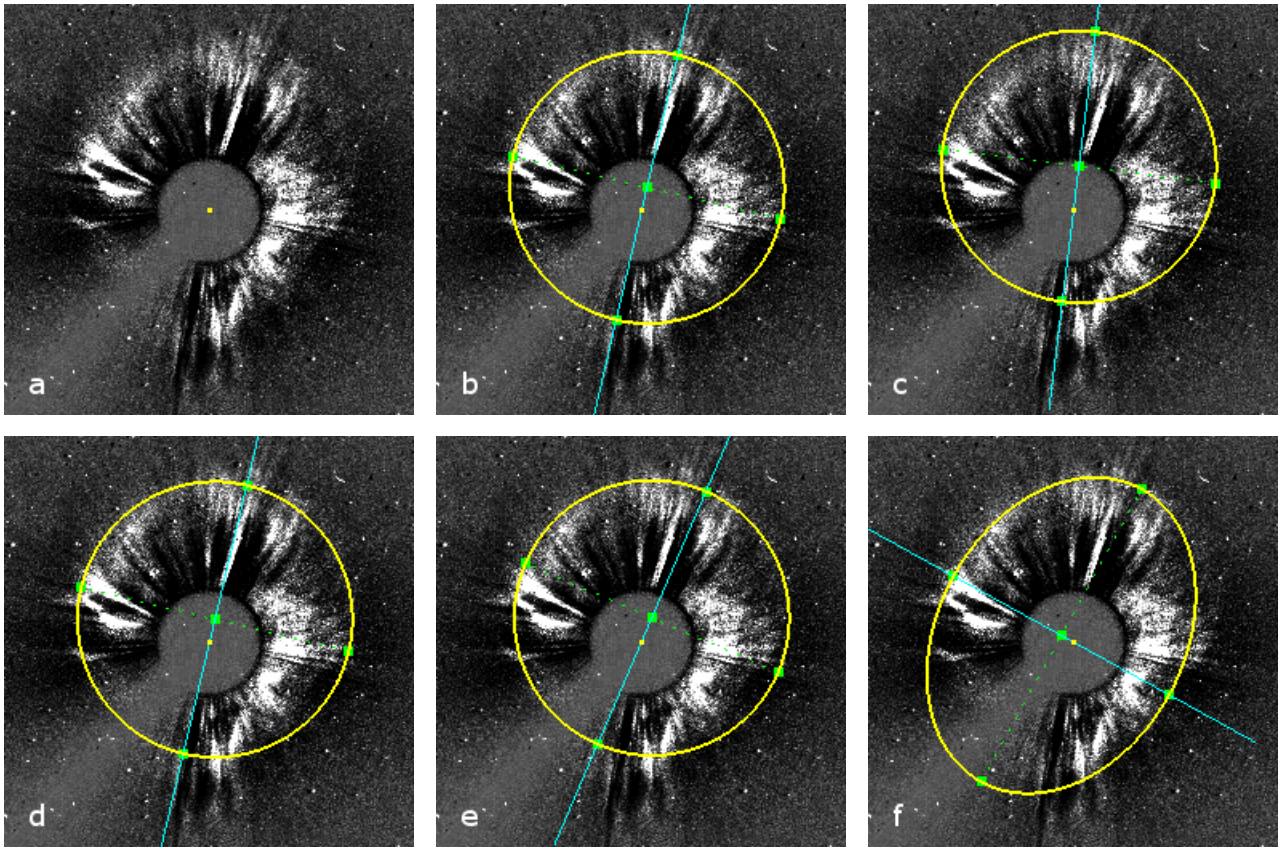
A second coronagraph image yields propagation velocity.



• Built the ellipse ‘cone’ formulation into an operational tool (user friendly interface to allow routine forecaster manipulation).

• Subsequent V&V studies (with guinea-pig ‘forecasters’) revealed the technique to be highly problematic in many real world situations.

Real-world testing reveals a problem: Which ellipse? (very subjective)



	Latitude (deg)	Longitude (deg)	Cone ½ Angle (deg)	Radial distance (Rs)
b	9.1	2.3	43.2	14.7
c	9.4	1.3	26.9	22.3
d	0.7	0.2	4.4	132.4
e	3.8	1.7	20.3	29.0
f	20.8	-37.8	83.0	12.3

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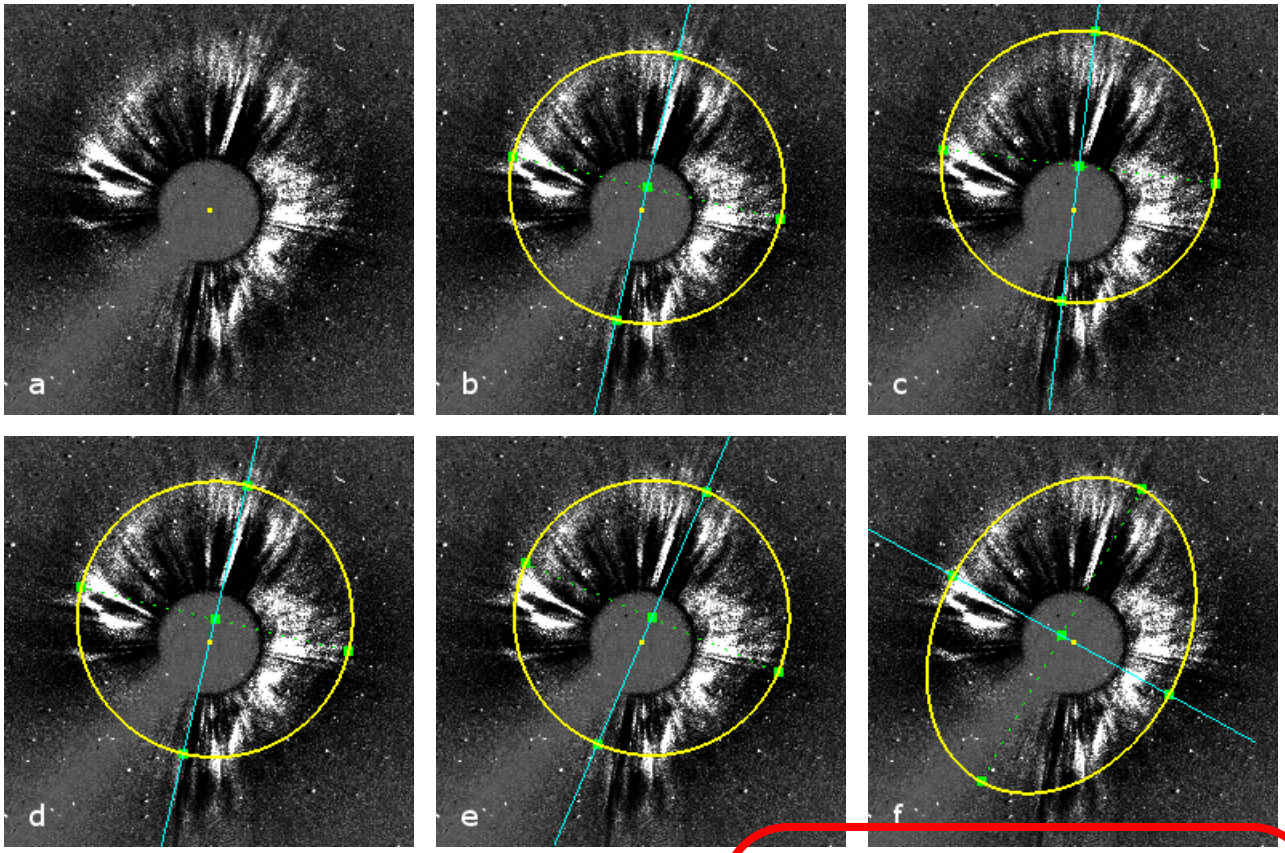

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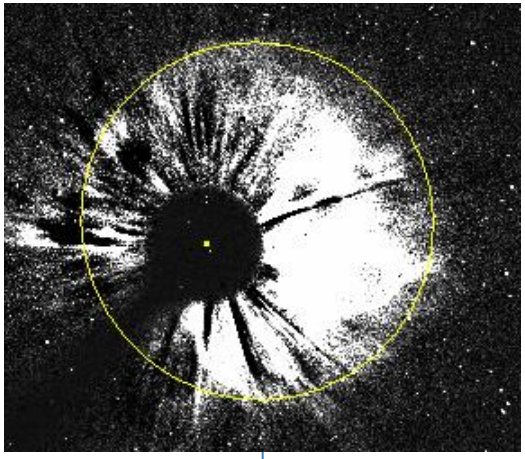
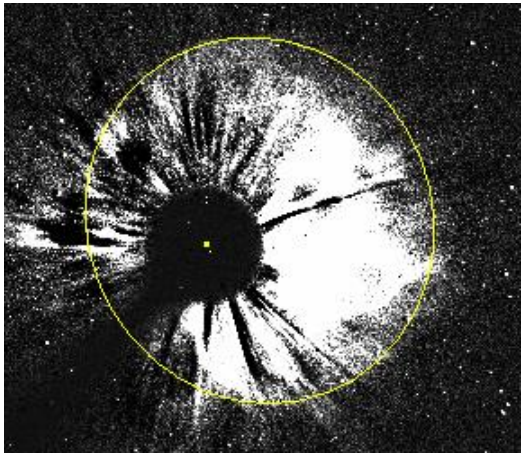
Cone ½ Angle

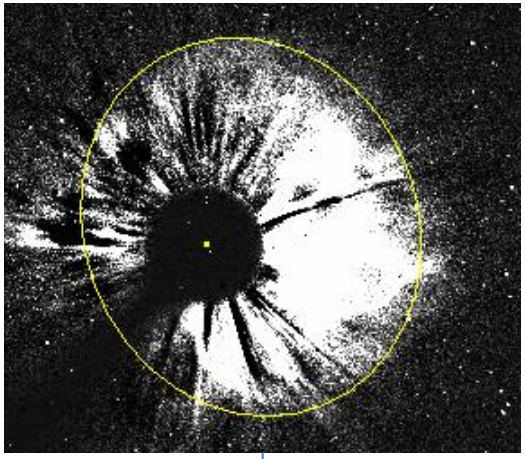
30 degrees



45 degrees

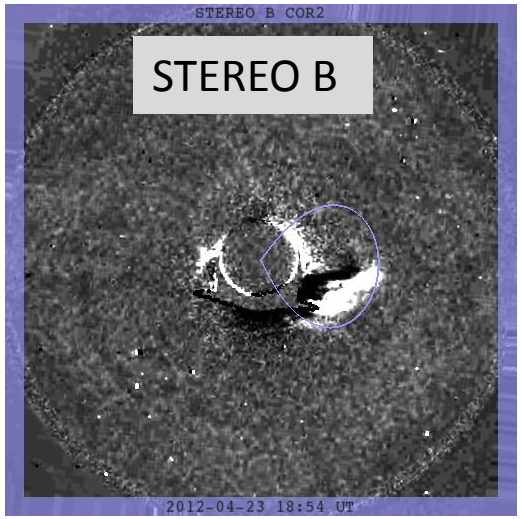


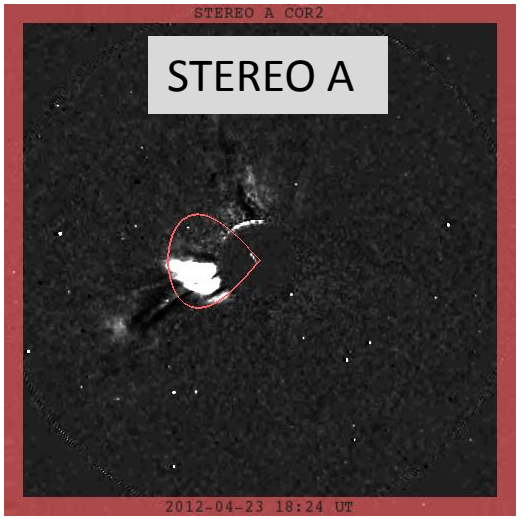
60 degrees

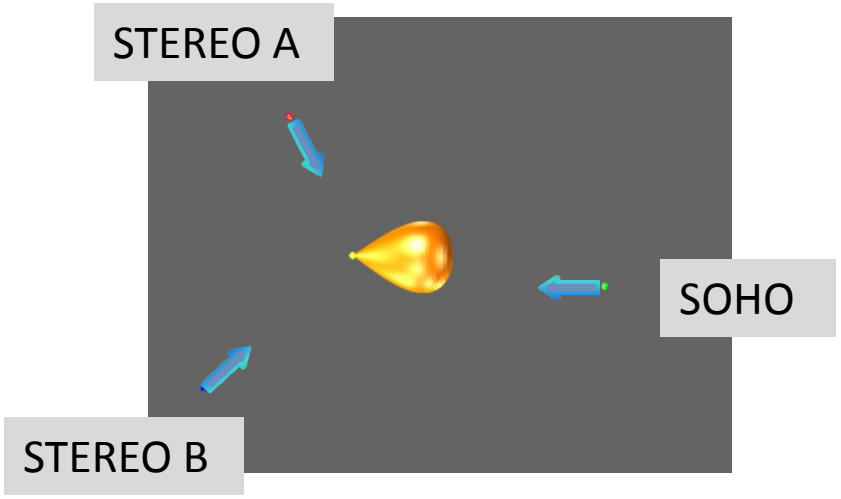


factor 2 difference
in velocity!!

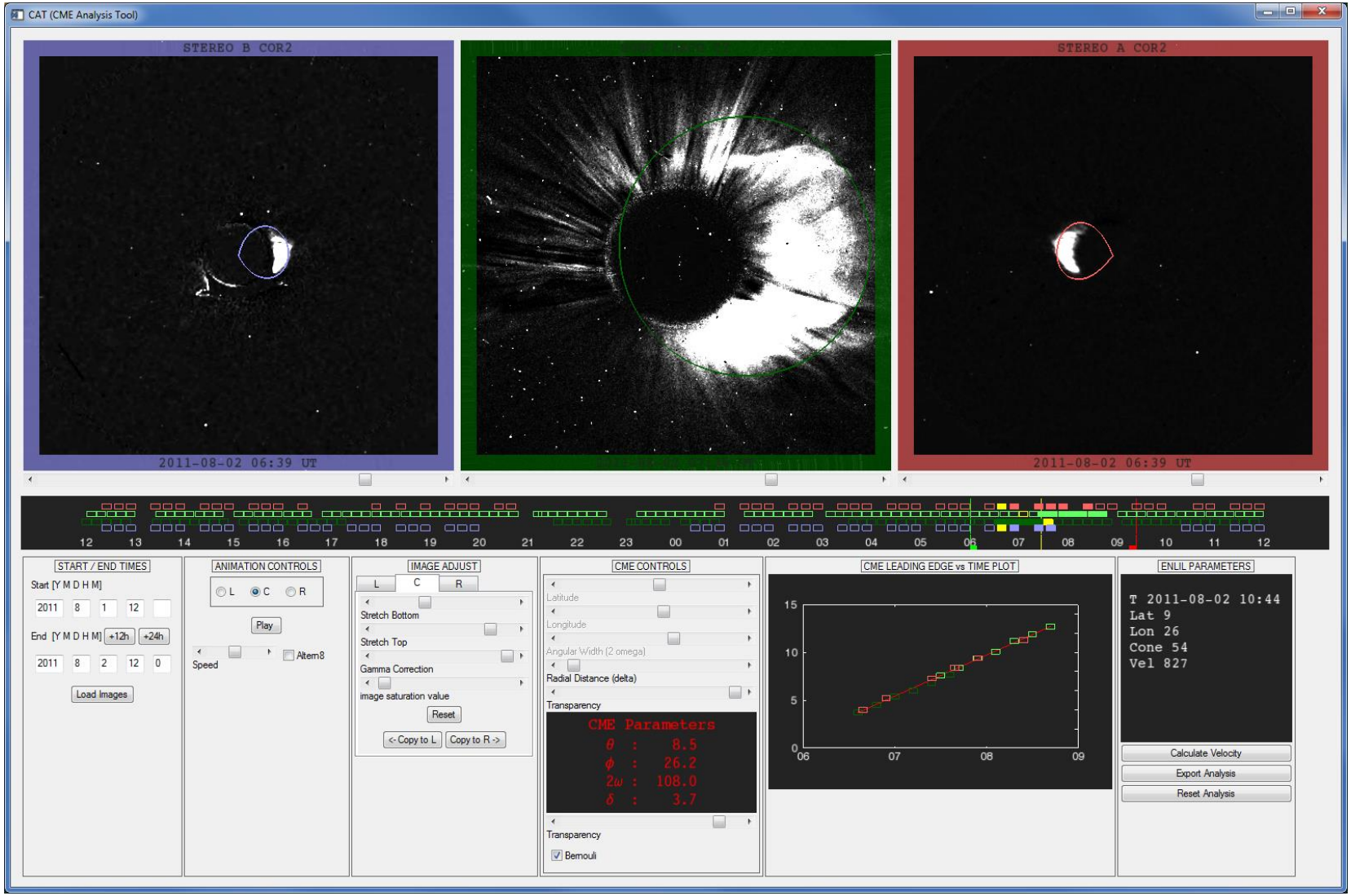
3D graphics modeling ‘3-view’ solution



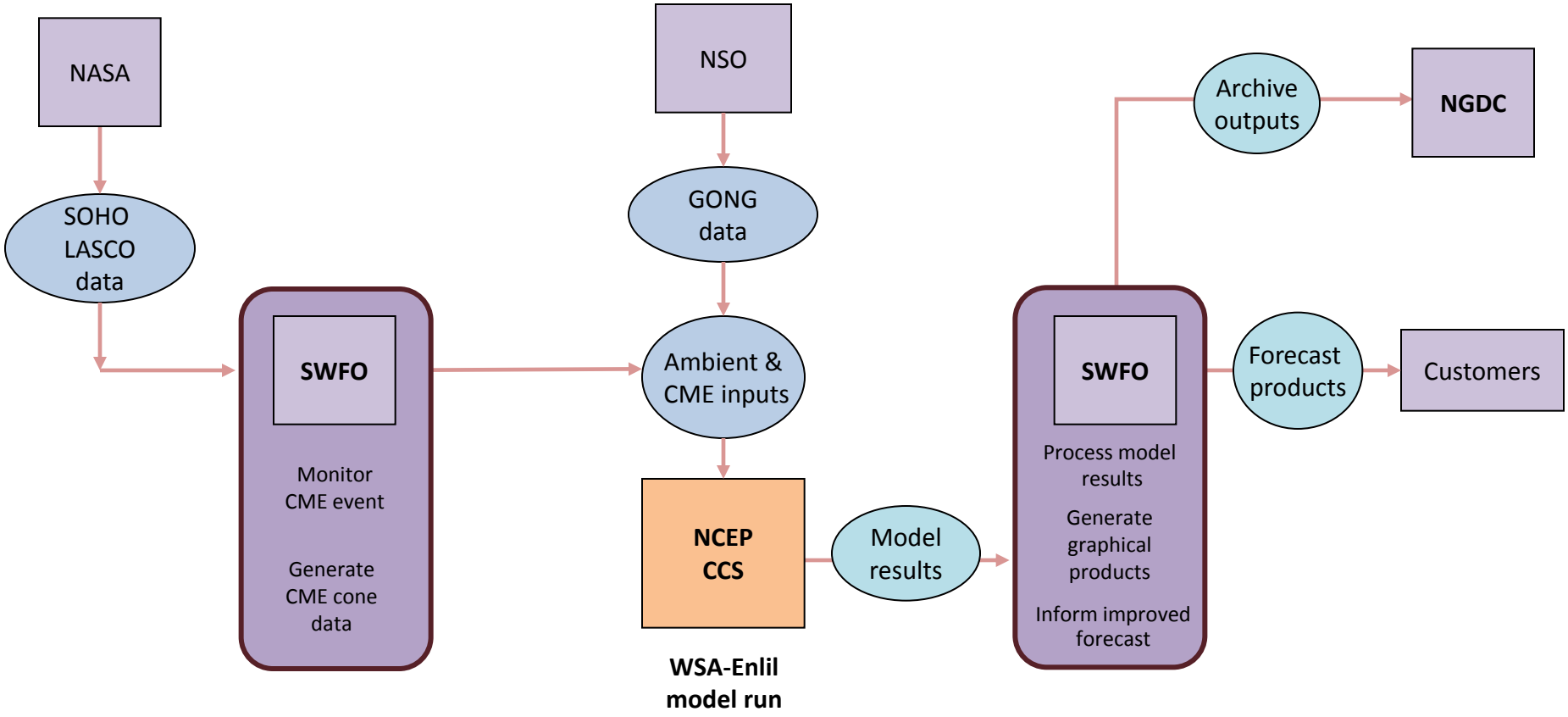




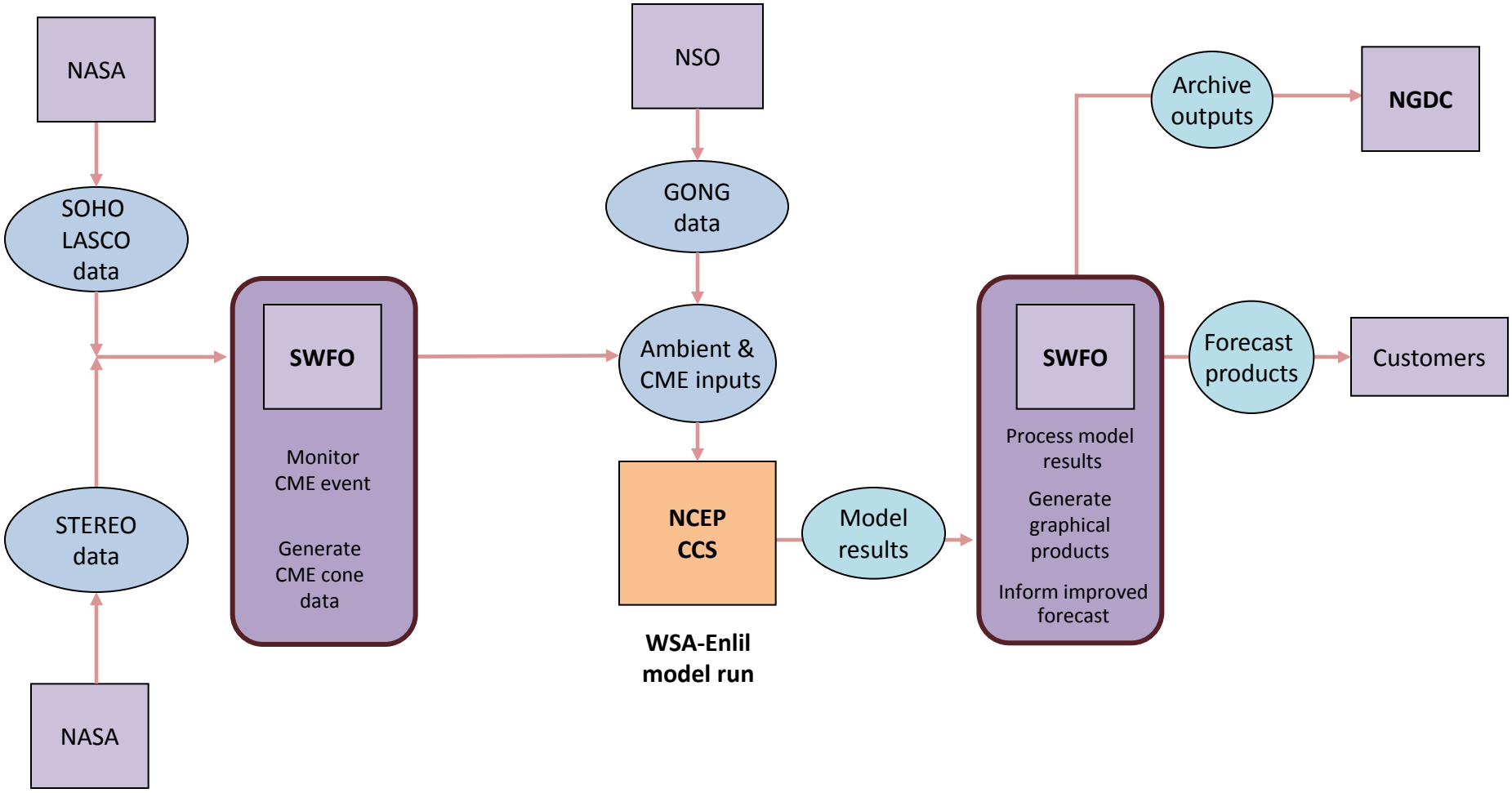
CME Analysis tool: Utilizes “3-view” from SOHO and STEREO A/B



WSA-Enlil CONOPS



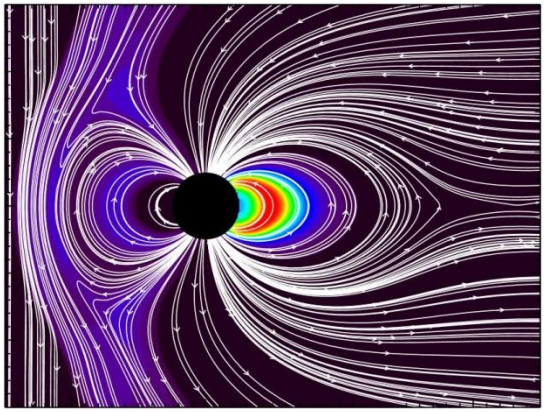
WSA-Enlil CONOPS

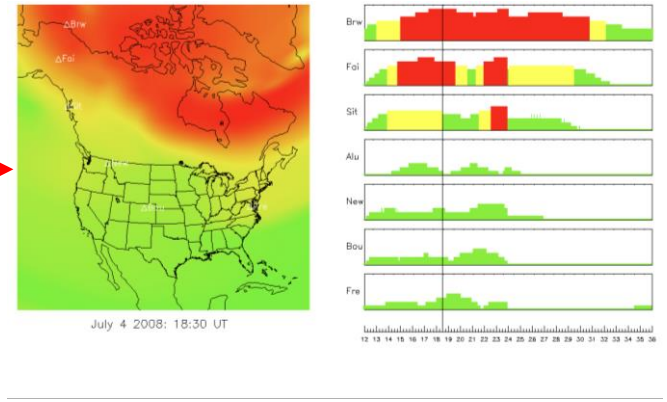


Forecasting Geospace

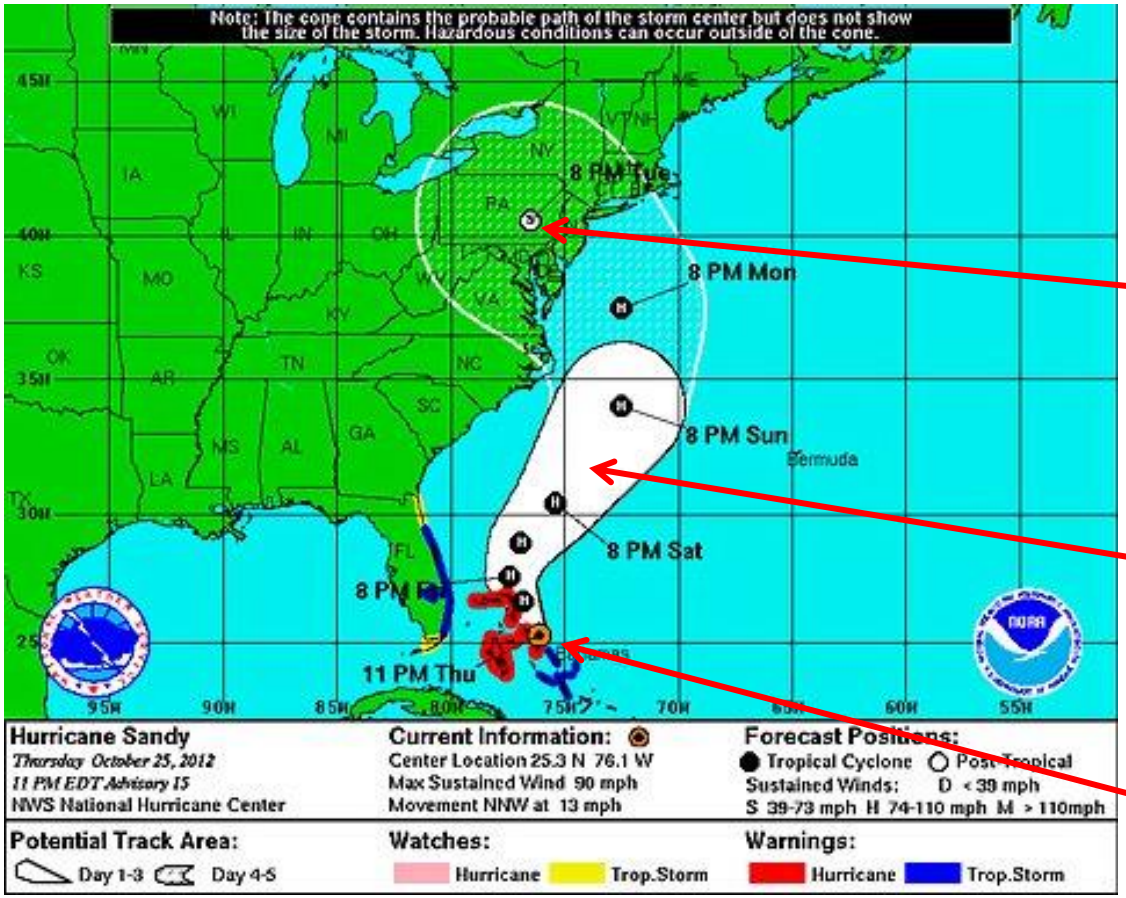
SWMF Magnetospheric Geospace model: 2014 – 2015

regional geo-magnetic activity prediction





NWS: Terrestrial weather forecast (example, Hurricane Sandy)



4-5 days into the future

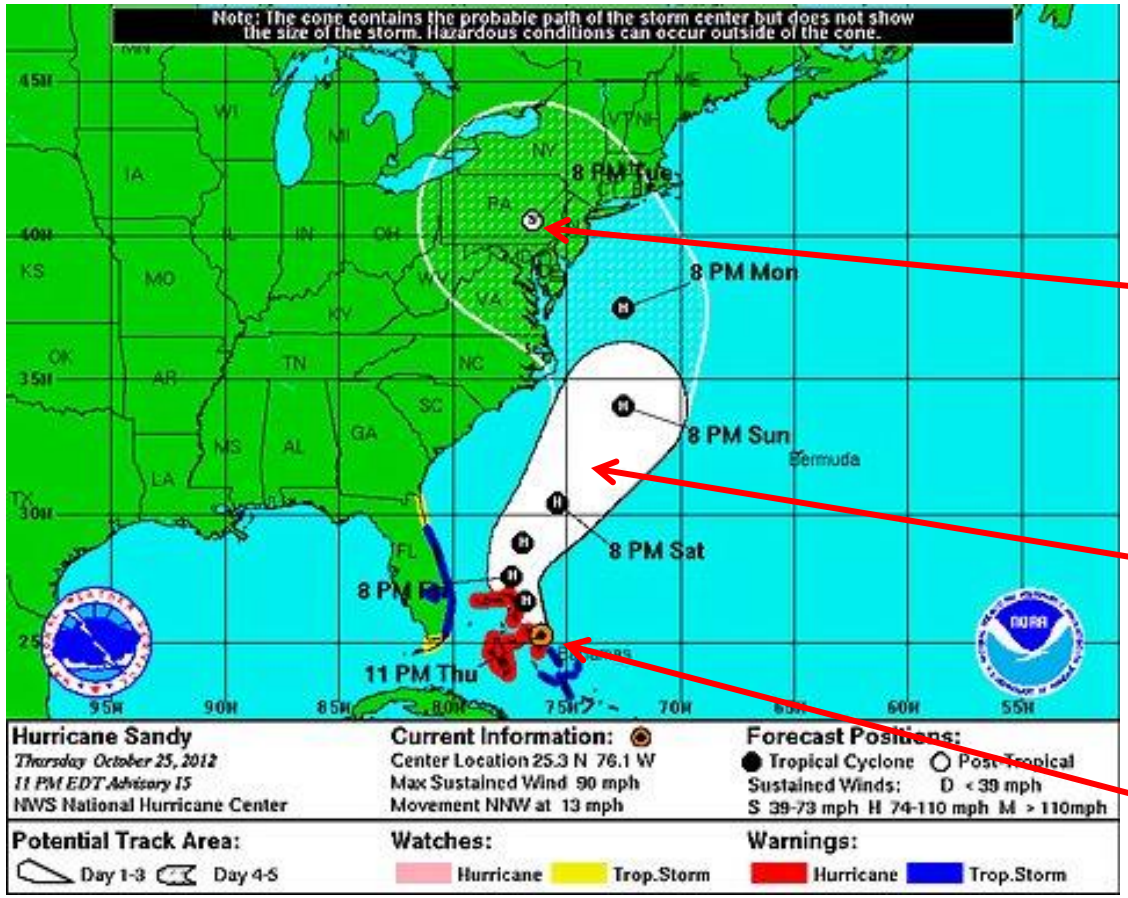
Model predicting 1-3 days into the future

Hurricane currently here

Obviously the models involved here are extremely complex, but predicting the future is possible because:

1) The 'state' of the system is known
2) The future inputs are known (the Sun will rise again etc.)

NWS: Terrestrial weather forecast (example, Hurricane Sandy)

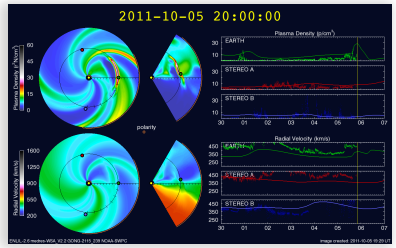


4-5 days into the future

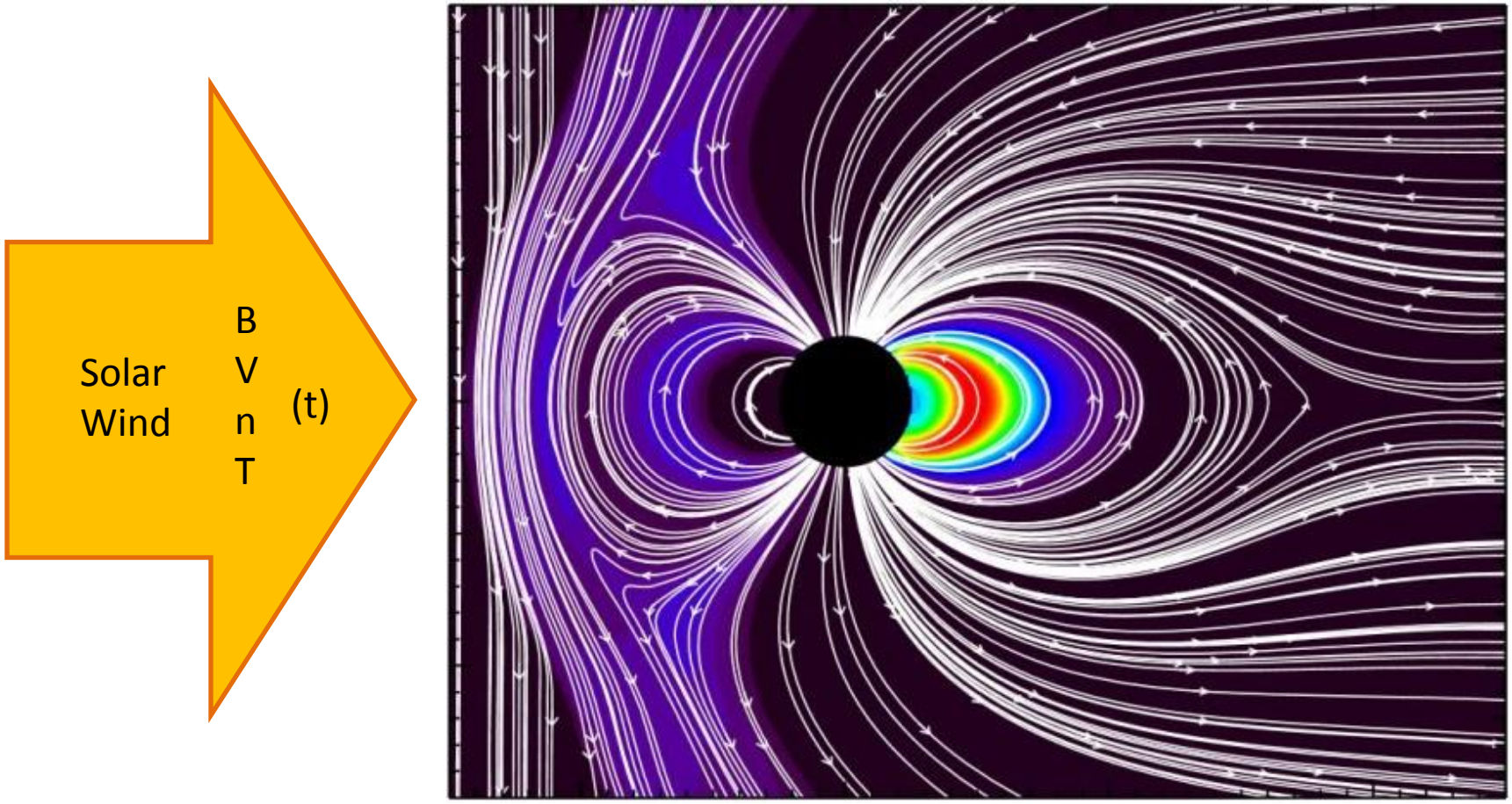
Model predicting 1-3 days into the future

Hurricane currently here

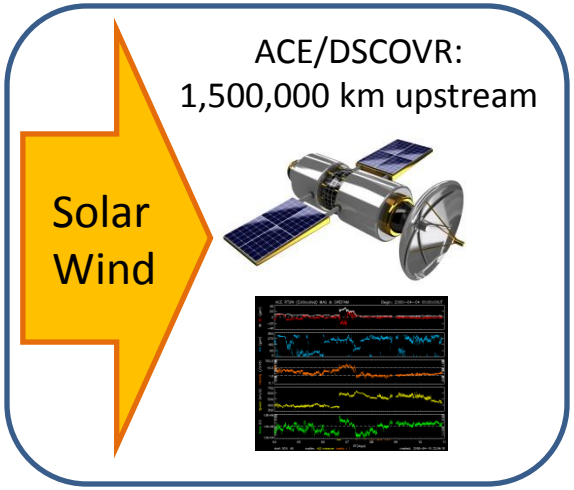
Enlil works this way too



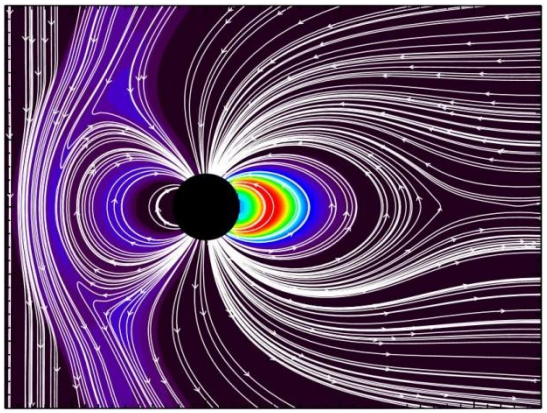
In contrast, the Magnetosphere is strongly driven by the dayside Solar Wind. This cannot be forecast into the future (not yet anyway) – it can only be measured in real-time……



….so if that's the case – how can we "forecast" anything ?



Lead time between 10 and 100 minutes
(dependent upon SW speed)



So the system is better described as a 'future nowcast'
(but lets not get caught up with definitions/semantics)

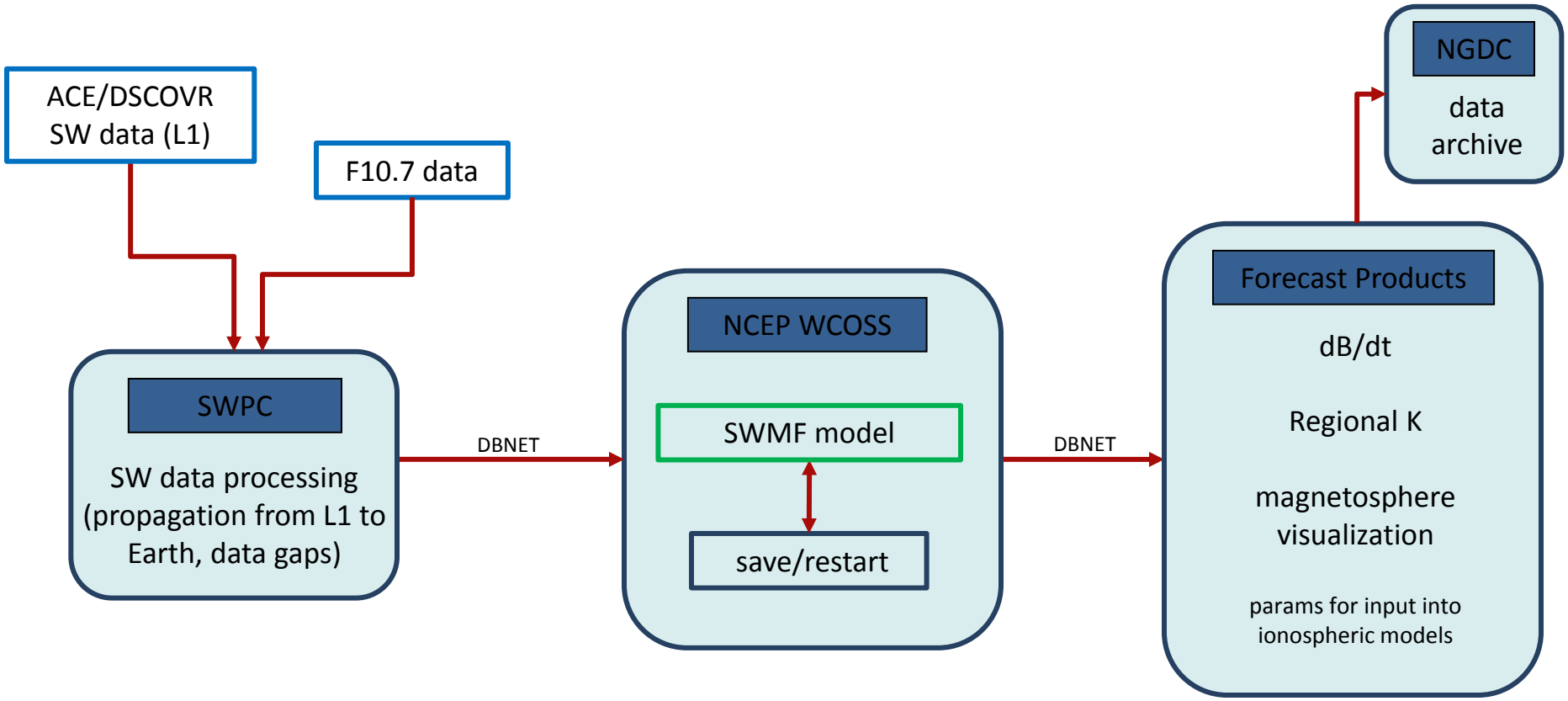
The important point:

Forecasting Geospace requires a real-time system

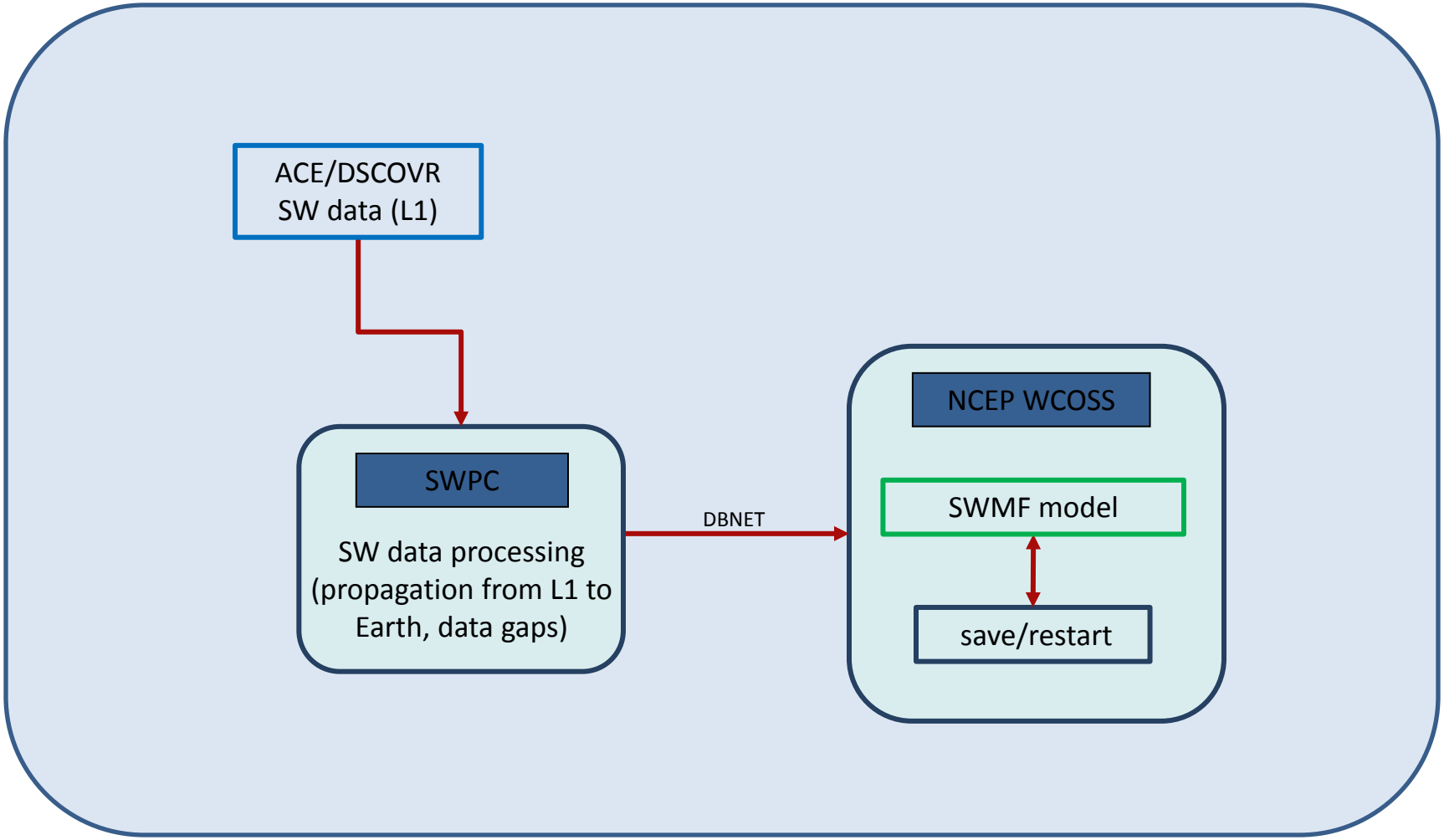
(the model needs to react immediately to incoming SW data).

Any delay will seriously eat into the forecast Lead time.

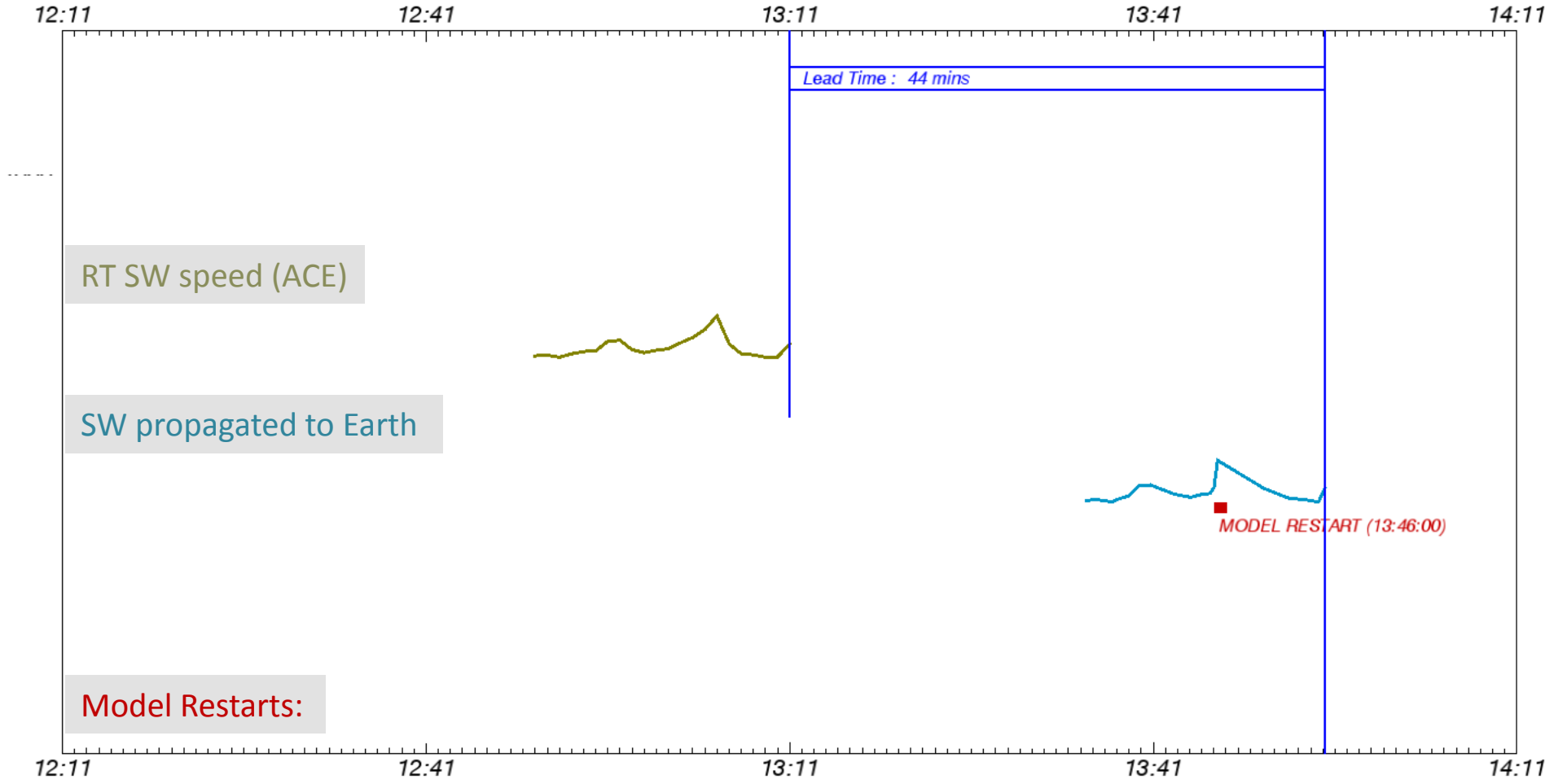
CONOPS: NWS Geospace forecast model



How can this work as a Real-time forecast system?

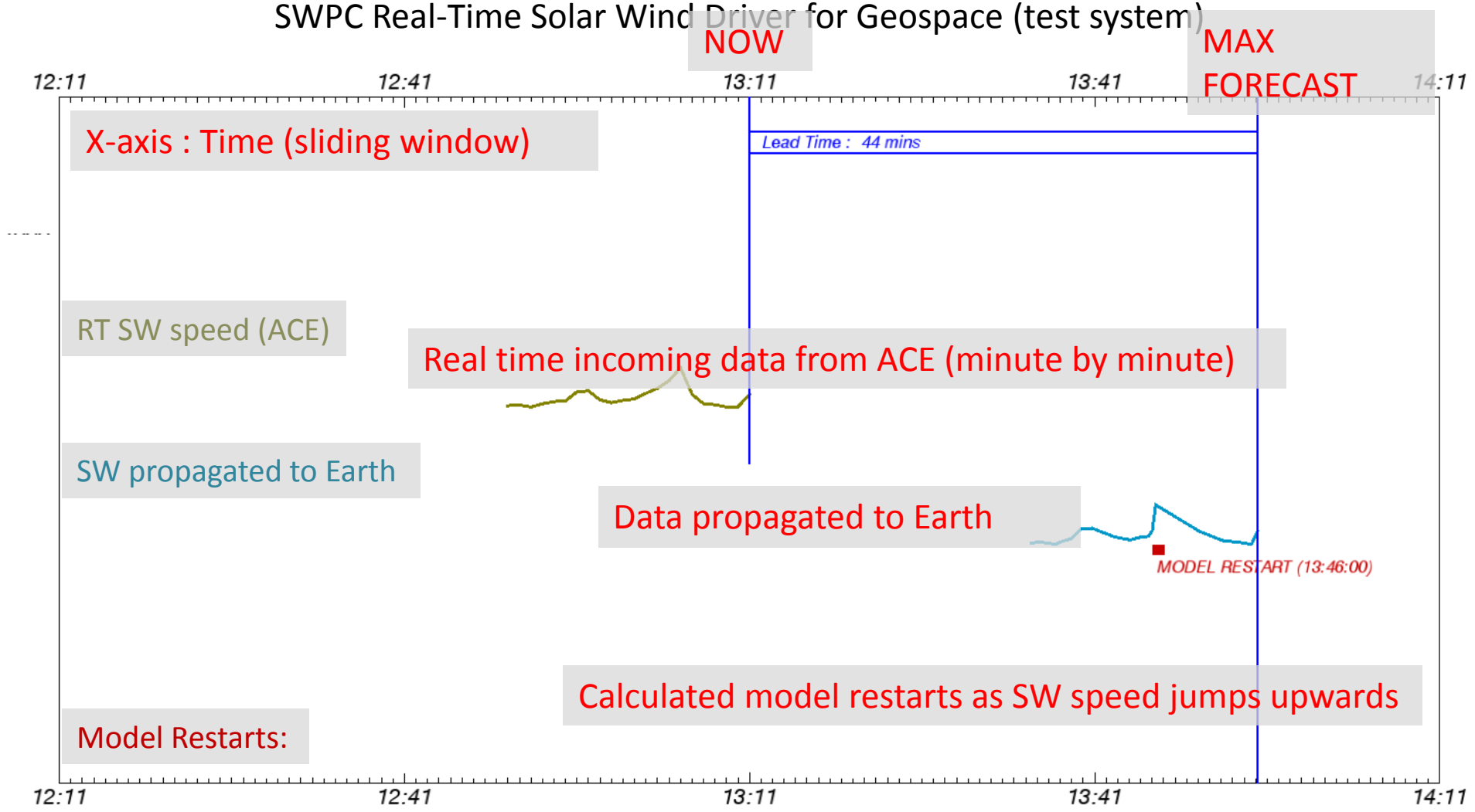


SWPC Real-Time Solar Wind Driver for Geospace (test system)




```
Wallclock : 13:11:00
Propagated : 13:55:08
SWMF: MODEL RESTART at : 13:55:00 File : SWMF_2006-12-14T13:55:00.rst
Model Run from 13:55:00 to 13:55:08 (Timestep :   8s)
SW speed (t-1) -> (t) :   547.81 ->   548.33
```

SWPC Real-Time Solar Wind Driver for Geospace (test system)

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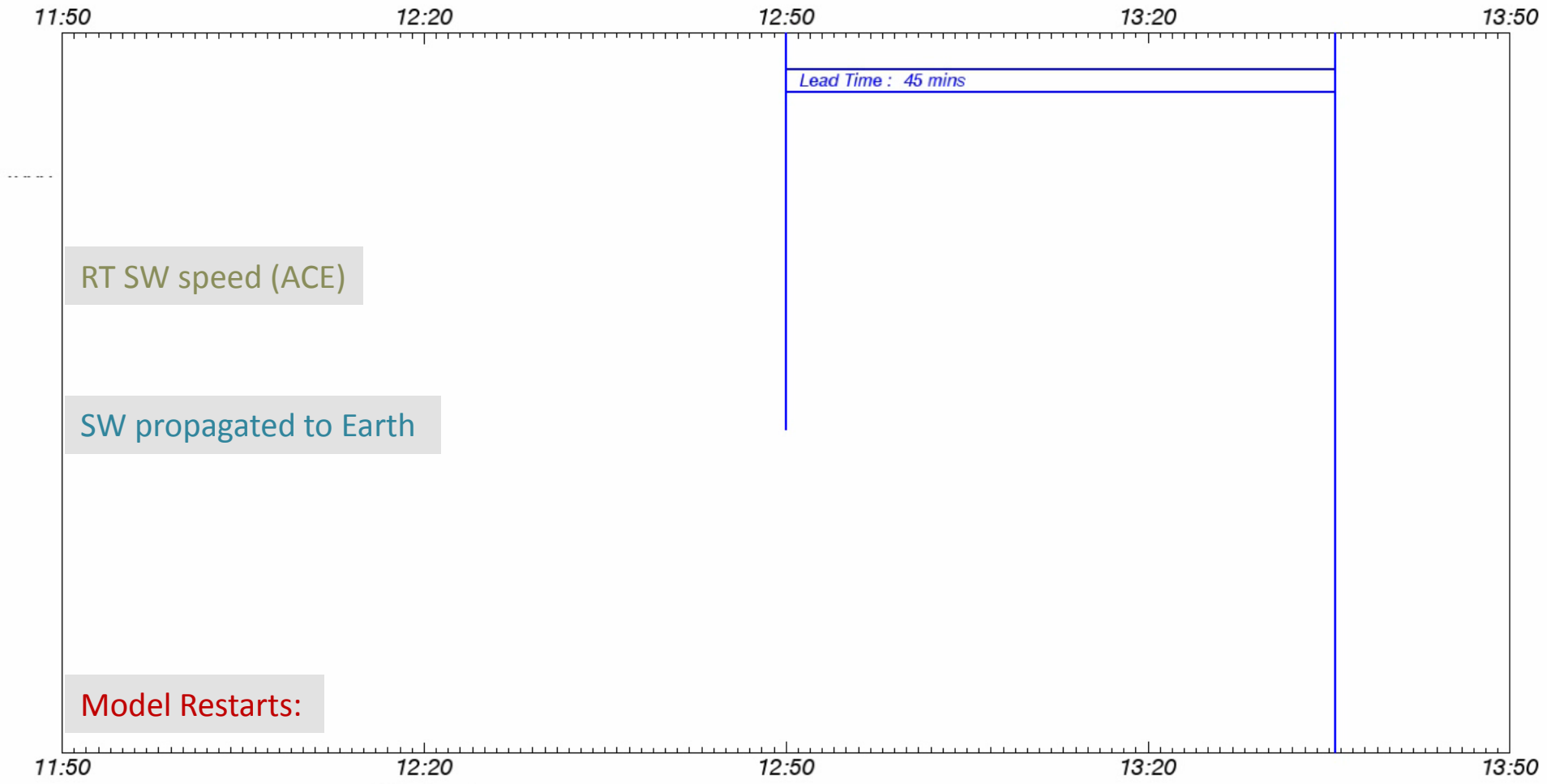
SW speed (t-1) -> (t) :   547.81 ->   548.33
```

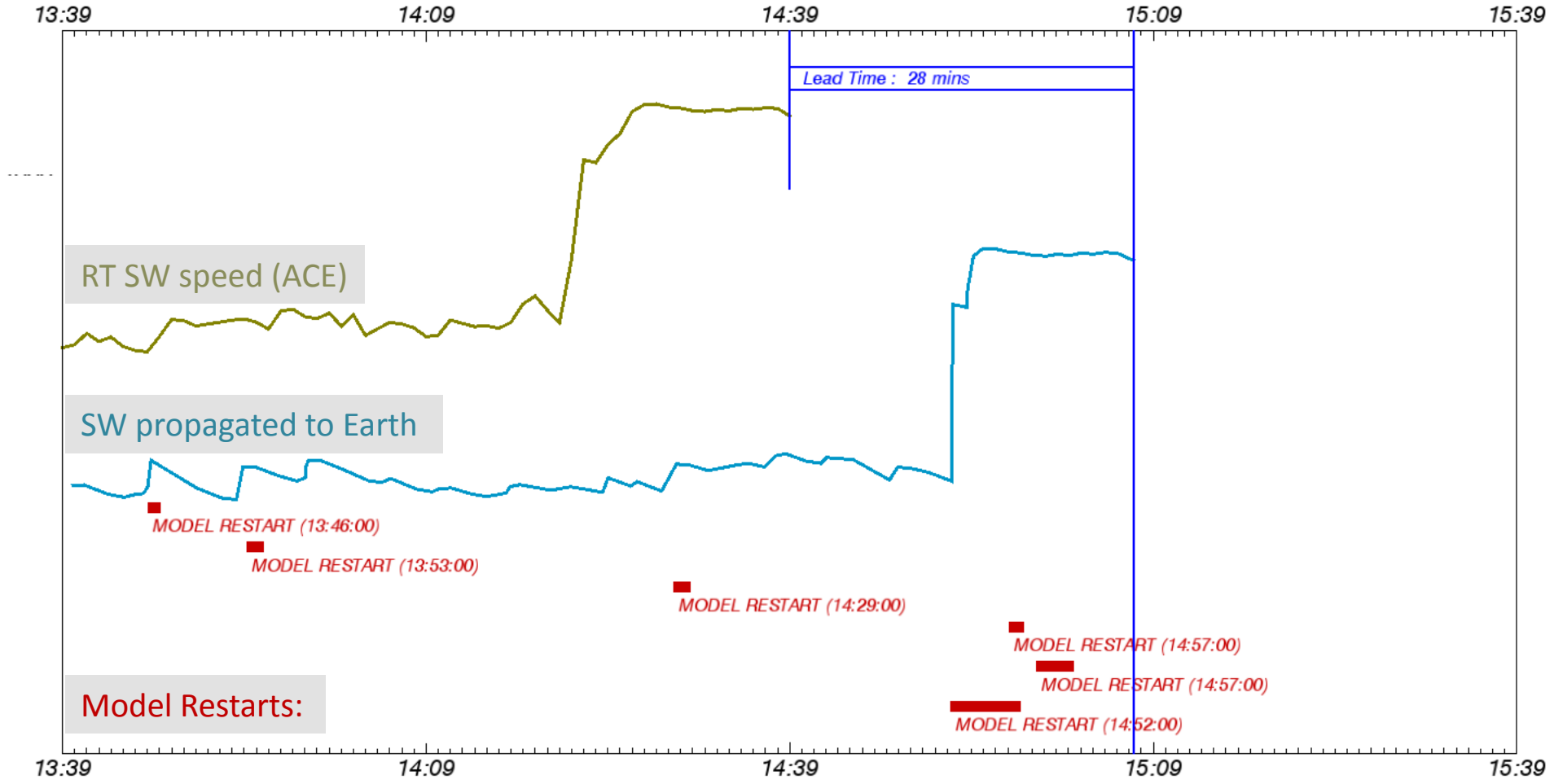
Data that SWMF needs at each time step to run

SWPC Real-Time Solar Wind Driver for Geospace (test system)



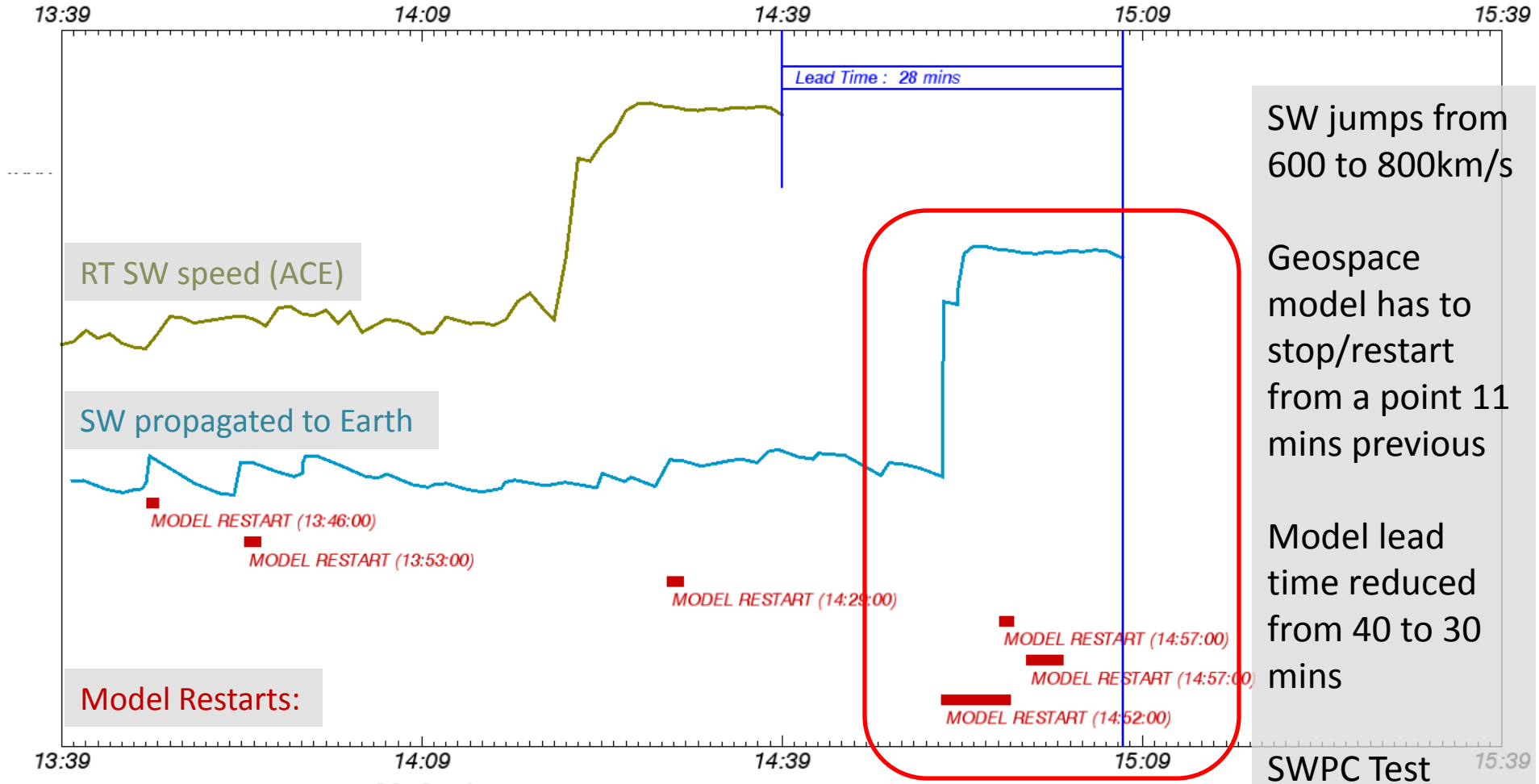

```
Wallclock  : 12:50:00
Propagated : 13:35:27
SWMF : NORMAL (SOLARWIND INCREASING)
Model Run from  to 13:35:27 (Timestep :    0 s)
SW speed (t-1) -> (t) :     0.00 ->   549.94
```

SWPC Real-Time Solar Wind Driver for Geospace (test system)




```
Wallclock  : 14:39:00
Propagated : 15:07:21
SWMF : NORMAL (SOLARWIND DECREASING)
Model Run from 15:06:01 to 15:07:21 (Timestep :  79 s)
SW speed (t-1) -> (t) :   892.08 ->   881.82
```

SWPC Real-Time Solar Wind Driver for Geospace (test system)




```
Wallclock  : 14:39:00
Propagated : 15:07:21
SWMF : NORMAL (SOLARWIND DECREASING)
Model Run from 15:06:01 to 15:07:21 (Timestep :  79 s)
SW speed (t-1) -> (t) :   892.08 ->   881.82
```

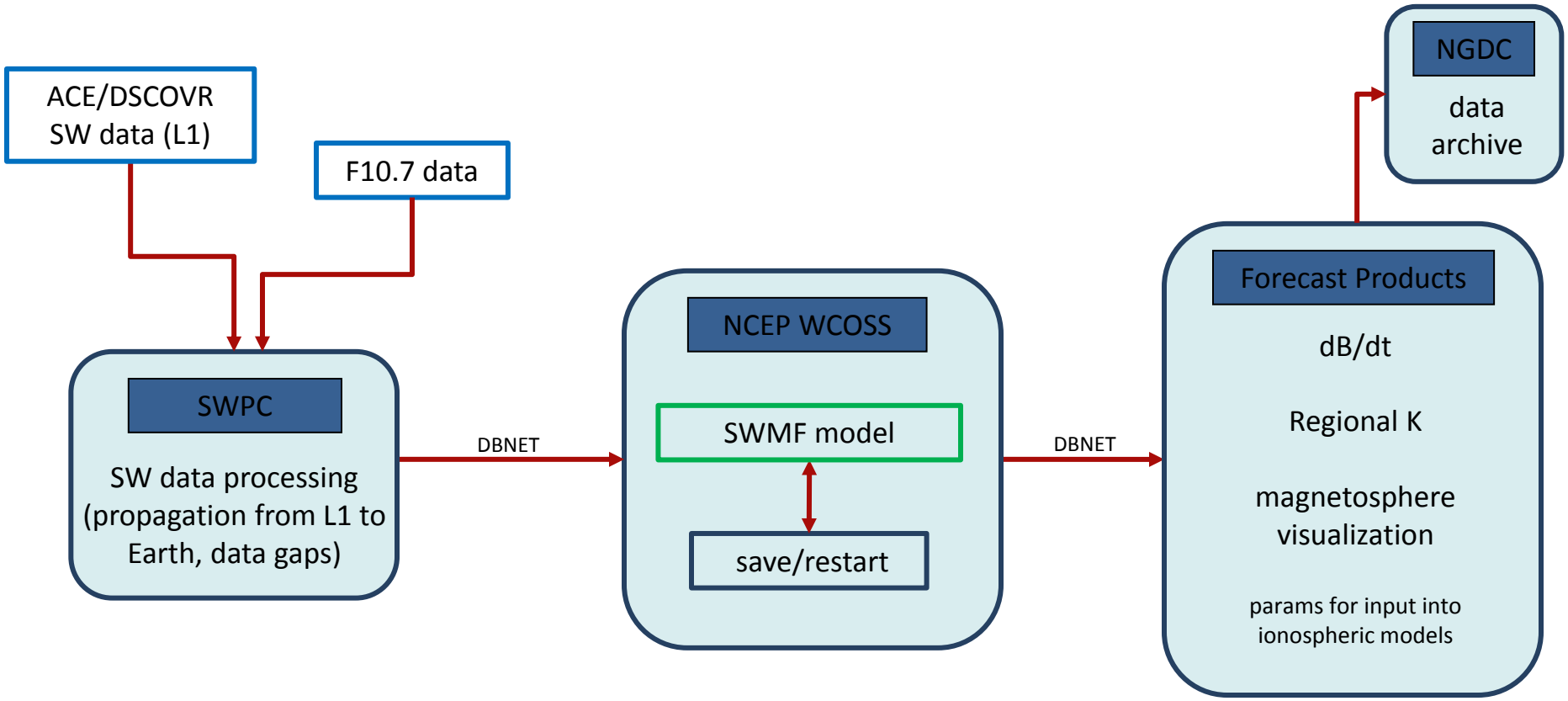
SW jumps from 600 to 800km/s

Geospace model has to stop/restart from a point 11 mins previous

Model lead time reduced from 40 to 30 mins

SWPC Test system shows it can all be achieved in RT

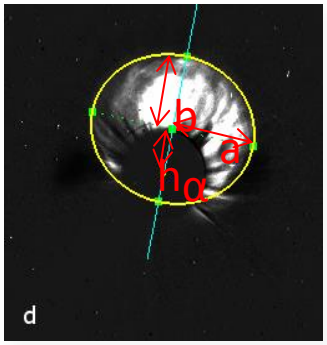
CONOPS: We're working on it!!



So, Geospace is a done deal then right?

No, of course not:

remember



Many challenges ahead – but it's fun
We'll get there!!